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ABSTRACT

This paper describes a specific case study of the development of a continued evaluation program in science education. Introduced is the Audio-Tutorial Elementary Science Project (A-TESP) developed by Joseph D. Novak, which provides a model of program development, implementation, and evaluation. Three phases, characterized as the pre-developmental, curriculum development, and research, are discussed. Data are presented to emphasize the need for continuous program evaluation, even after program development is completed. (CS)

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A Model for Program Development and Evaluation: The Formative Role of Summative Evaluation and Research in Science Education.[1]

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Paper prepared for presentation at the 12th Annual Conference of the International Congress for Individualized Instruction (ICII) to be held in Windsor, Canada, 1980.

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Introduction

In an effort to contribute to the literature on evaluation in science education, a specific case study of one program's development, implementation, and evaluation is presented. The case study itself is preceded by a theoretical introduction to various concepts of evaluation. However, the theoretical section is brief for several reasons: First, there is a vast basic literature to which the novice in educational evaluation can refer; second, I wish to concentrate my discussion on a general model which does not yet appear in the literature; and, finally, my aim is to draw specific conclusions about evaluation which will add to the wealth of existing theoretical literature rather than recapitulate what has already been said.

The purpose of this paper is to stress the importance and necessity of continued program evaluation. A general model of program development and implementation which consists of three separate phases will be introduced. This model is based on a case study of one specific program, the Audio-Tutorial Elementary Science Project (A-TESP), developed by Novak (1972a, b). Each phase in the development and implementation of this program has utilized a different approach to evaluation. After the model has been presented, it will be possible to draw conclusions concerning long term evaluation. This will be done with specific examples which have been excerpted from the A-TESP content during a recent research effort (Pines 1978).

The combination of a descriptive study of long-term program development and implementation with recent empirical data pertaining to that program results in a conclusion of importance to the domains of evaluation and science education.

Evaluation

The concept "evaluation" is broad and multifaceted. The term "evaluation" itself refers to numerous different types of activities which occur within many different contexts, at a variety of levels, and for a number of diverse purposes. Because of this general applicability, I think that evaluation may become an abused domain if precautions are not taken to clarify the concept and to circumvent obfuscating its different facets.

In general, "evaluation" refers to the process where data is collected to estimate the merit or worth of some entity or process. The entity may be a person, a program, a painting, a piece of furniture, and so forth; the process may be that of personal growth, penmanship, curriculum development, research methodology, or even an evaluation strategy.[1] Thus the objects of evaluation are countless.

But there is another dimension to evaluation that must be considered, namely the reasons for evaluating. Will the evaluation be used in decisions concerning the adoption of a program or the

purchase of a piece of equipment? Will a person be hired, promoted, or fired, depending on the outcome of their evaluation?

The above two dimensions are often confused both in the literature and in practice. That is, the goals of evaluation are often confused with the roles of evaluation. The goals of evaluation should always include the estimation of merit, worth, value, and so on; although one may choose to stress either the constructive or the decision-making roles (See Scriven 1967).

Michael Scriven (1967)[2] has attempted to clarify these and other aspects of evaluation.[3] The different facets of Scriven's paper are clearly beyond the scope of this paper, but we do rely heavily on his conceptual clarification throughout our presentation. Of special interest to us are the roles of "formative" and "summative" evaluation which he has defined.

Briefly, Scriven has said: In the formative role, the evaluation feedback loop stays within the developmental agency...and serves to improve the product. Whereas in the summative role, the evaluation information goes outside the production agency and serves to improve utilization or recognition of the product.[4] The concepts of formative and summative evaluation have been summarized by Ahmann (1967). These concepts will become more clear as we turn now to our case study and model.

The A-TESP: A Model of Curriculum Development and Implementation

The Audio-Tutorial Elementary Science Project was developed at Cornell University by Joseph D. Novak with the help of his graduate student associates.[5] The program was developed for the dual purposes of teaching scientific concepts to elementary school children and simultaneously investigating the acquisition of these concepts by the children.

We will limit ourselves to a brief summary of the development and implementation of the A-TESP upon which our model is based.[6] The first phase of development was a "pre-developmental stage". In this stage, a few lessons were constructed and evaluated, which resulted in the knowledge "that the A-T approach was effective in teaching children concepts of plant growth and electrostatics" (Novak 1972a).[7] Essentially during the pre-developmental stage, the main objective was to decide upon the curricular content of the program. That is, the concepts were chosen which the students were to learn.[8]

During the second phase of the program, "some sixty A-T lessons were ... developed and field-tested with students ... from 1965 - 1971" (Hibbard and Novak 1975). These lessons were created as self-

contained, pre-packaged modules. During this second developmental phase, evaluation was also formative in an endeavor to improve instruction and ameliorate curricular deficiencies.[9] In contrast to the "pre-developmental stage", where the developers were mainly concerned with curriculum development, the primary interest during the second phase was instructional development. This "developmental stage", mainly involved try-out implementation of the instructional materials developed and an empirical investigation of the effectiveness of these materials. The purpose of the data collection and analysis was to improve instructional materials, that is, decisions were made during this second phase concerning the instrumental content to be used in teaching the curriculum.[10]

Theoretically, this recursive approach to lesson development, where there is a continuous honing of instructional material, can go on endlessly.[11] Such instructional improvement is, however, subject to the Law of Variable Proportions or Diminishing Returns as shown in figure 1.

Place Figure 1 Approximately Here

Thus there is a point where the developers must decide to arrest further fixing in favor of implementing the program. In the case of the A-TESP, approximately 200 man hours were devoted to the testing of each of the 50 lessons developed. Novak (1975) summarizes this second phase as follows:

> In the course of subsequent tryout with other samples of children and six to eight further revisions, an audio-tutorial lesson is almost guaranteed to teach something to all children of the age or grade-level for which it is intended. We might say that the design of A-T science lessons leads to some assurance that at least minimum learning will occur.
>
> Most teachers and school administrators want more evidence that A-T lessons can teach science than is provided in our lesson development procedures. Partly for this reason, but especially for research purposes, we have devoted major energy to the evaluation resulting from A-T instruction. (p.V108)

By the end of the second "developmental stage", all gross limitations in student vocabulary and necessary equipment manipulation ability should have been taken into account. Investigations uncovered certain commonalities amongst the children regarding their linguistic facility, their manipulative dexterity, and their prior knowledge of key A-TESP concepts. This knowledge was then used in the revision of both lessons and administrative aspects of the program.

The third and final phase of the A-TESP involves both summative evaluation and research on learning theory. This phase began approximately in 1971 and continues to date. Children who participate in the project were evaluated prior to, during, and subsequent to the A-TESP lessons (Pines et al. 1978). This evaluation supplies the data necessary to estimate the effectiveness of the program, and to investigate the process of concept acquisitions.

The phases of the A-TESP, from a curricular and instructional framework, are depicted in Figure 1. This description provides a general scheme of program development, implementation, and evaluation. The first phase of the model is "pre-developmental" and concerns selection of curricular concepts. The second phase is "developmental" and involves the construction and testing of instrumental or instructional content. Both of these phases rely purely on evaluation in a formative role. The third and final phase, which evolves from the former two, includes research and evaluation which have been summative. In the empirical portion of this paper that follows we hope to make evident that the final phase can and should play a formative role too.

Research and Evaluation Data

One small segment of the A-TESP content will be excerpted to highlight points apropos to this paper. We will start by describing that portion of the A-TESP necessary to understand the data. Then empirical evidence from a number of case studies of elementary-aged A-TESP users will be offered.

The concept which we have chosen to examine here is that of "life". The A-TESP attempts to teach the concept of "life" in relation to the other key concepts, such as "energy". The concept of "life" is related to the concept of "growth". "Seeds" are used as one of the exemplars of living things. Within the framework of the A-TESP, children listen to taped lesson dialogues about seeds and plant growth. Along with other related concrete experiences, they plant their own seeds and subsequently observe the growth of plants.

In this study[12], approximately 100 children were interviewed prior to using the A-TESP, in an attempt to ascertain their conceptual knowledge of "life". Then after working with the A-TESP lessons, 126 children were interviewed on three different occasions to assess changes in their conceptual structures. The Modified Piagetian Clinical Interview (MPCI) and the Conceptual Propositional Analysis

(CPA), which were used for generating and analyzing the interview data, have been outlined in Pines et al. (1978)[13].

Following are a few excerpts from the data collected pertaining to the concept of "life". The children, in each instance, were questioned about "life" via concrete props; in this case, seeds. The children's responses during the pre-instructional interview (PreII, administered prior to A-TESP instruction) appear on the left, opposite the propositions generated during the post-instructional interview (PostII, administered subsequent to A-TESP instruction). In each case, the PreII should be compared to the PostII.

The first excerpt which appears in Table 1 is one version of the type of ideal result which the A-TESP developers had originally hoped to achieve.[14]

Place Table 1 about here.

This child came to the lessons with the notion that seeds are alive. Consequently, she was able to provide a highly sophisticated response in the PostII.[15] This type of response was found, however, to be unique. In most cases, children came to the lessons with the idea that seeds are not alive. Consequently, their responses in the PostII reflect severe misconceptions concerning the "continuity of life", viz.,seeds are not alive but if supplied with the necessary conditions, they will become alive. Examples of this kind of misconception appear in Tables 2, 3, and 4.

Place Tables 2, 3, and 4 about here.

There is a difference between the misconceptions on the "continuity of life" in these children and the previous example (see table 1) in which no violation of the scientific accuracy of the concept occurred. Usually when a child came to the lessons with the misconception that seeds are not alive, then further elaboration of this misconception occurred subsequently during the course of the lessons. Aside from providing evidence that prior knowledge does have a profound affect on future learning (Ausubel et al. 1978; Pines and Novak 1980), such a finding raises questions about the adequacy of the lessons. In this case, we find that the lessons did not take into account the children's prior knowledge and thus failed to uproot or ameliorate existing misconceptions.

So common is the outcome of the above misconception, that one can almost predict the result of A-TESP instruction. The class of children which served as a control for the affects of the PreII in this study, received no PreII treatment. By looking at their PostII data, one can comfortably guess, with a high degree of confidence, how these children would have responded in the PreII if it had been administered. This is illustrated in Table 5.

Place Table 5 about here.

The data presented should suffice to emphasize that the A-TESP lesson content is, in this case, failing to achieve the desired outcome. Several excerpts from the lesson scripts will serve to illuminate the reason. These excerpts appear below:

"How will you know if a seed is alive?"

"When you see a seed start to grow, you will know the seed is alive."

This first example is taken from the A-TESP level I, lesson 13, p.9.

"You must watch the seeds that you planted and see if they grow...This corn seed is alive because its growing..."

"...because this bean seed in the next movie is growing, we know it is alive."

This second example is taken from level I lesson 14, pp. 2-4. Many additional examples that can unwittingly reinforce misconceptions exist in the A-TESP. However, these examples from the lesson content are exemplary.

Such lesson content interacts differentially with different cognitive structures (Pines 1978a) to yield the results described above (cf. Tables 1-5). When children believe that seeds are alive and listen to the lesson content presented below (p.11)they can understand the A-TESP developers' intent[16] concerning the relation between "life" and "growth". Whereas, when children believe that seeds are dead and listen to that same content, they justifiably incorporate the lesson content with the misconception that dead seeds spring to life (observed as growth) when the necessary requirements for germination are met.

What remains to be carried out is an analysis of these deficiencies of the A-TESP content and an appraisal of how such deficiencies can be ameliorated; the central purpose of this paper being to show that program evaluation data (both summative and research) can and should always serve as feedback (that is, play a formative role) in program development. Cronbach (1963) has made several fitting comments in accordance with our findings:

> Evaluation, used to improve the course while it is fluid, contributes more to improvement of education than evaluation used to appraise a product already placed on the market...The greatest service evaluation can perform is to identify aspects of the course where revision is desirable...
>
> ...Insofar as possible, evaluation should be used to understand how a course produces its effects and what

> parameters influence its effectiveness...
>
> ...Hopefully evaluation studies will go beyond reporting on this or that course, and help us to understand educational learning. Such insight will in the end contribute to the development of all courses rather than just of the course under test...
>
> Even if the right data are collected, evaluation will have contributed too little if it only places a seal of approval on certain courses and casts others into disfavor. Evaluation is a fundamental part of curriculum development, not an appendage. Its job is to collect facts that the course developer can and will use to do a better job, and facts from which a deeper understanding of the educational process will emerge. (pp. 47-48, 58)

Eisner (1978) has more recently summarized these same ideas.

> Simply knowing the final score of the game after it is over is not very useful. What we need is a vivid rendering of how that game is being played. (p.622)

The Amelioration of Inappropriate Content: An Analysis

What is the problem with the lessons? First of all, obviously, the lessons have failed to uproot a misconception. Worse still, they

have caused this misconception to become further differentiated. Indeed the misconception which pertains to the "continuity of life" is more disturbing than the mere fact that a child does not know that seeds are alive. This is because the former constitutes curricular content, that is, the concepts of "life" and the "continuity of life," are content to be learned; whereas the latter--seeds as exemplars of "life"--is only instrumental content toward the end of acquiring the curricular content.

The reason that the A-TESP lessons fail with this specific content can be attributed to two major groups of problems:

1) The lessons have differentiated the concept of "life" emphasizing "growth" as a criterial attribute for "life", without stressing that the exemplars used (seeds) are examples of living things. The fact that seeds are alive is indeed never underscored. Thus the possible misconception that all seeds are dead is never challenged and never uprooted. Either the lesson developers were unaware that this misconception is prevalent amongst more than 80% of the children (See Pines 1977), or they naively expected that without special emphasis on the fact that seeds are alive, the children would be able to deduce this via the A-TESP emphasis on the "continuity of life".[17]

2) To say that all that needs to be done is to emphasize that seeds are alive, would be misleading however. The problem is more fundamental than that. Rather, certain important related concepts

are lacking from the lessons. Without these additional concepts seeds cannot be used as examplars. The concept of "dormancy" or "quiescence" is of fundamental importance; so too is the concept of "germination".

A child has reason to believe that seeds are dead because, as the children with this misconception say, "they just sit there and do nothing". Why should seeds be considered differently from rocks, pebbles, or beads? They look and feel very much the same. The imminent reason that seeds must be alive derives from the "continuity of life", the very concept which we are trying to differentiate. That is, seeds like chicken eggs are a link between one generation and the next; or after Samuel Butler, a chicken is only the egg's way of making another egg. With seeds, this can only be understood when the concept of "dormancy" (a state in which life is inherent but metabolism, growth, and development are arrested) is simultaneously introduced. In addition, the concept of "germination" (in which the potential of life is realized and growth is manifested), must be explicated.

Dormancy can be explained to children in many ways. One way is to use the concept of "sleep" which is familiar to all children. J. Bronowski (1973) has illustrated this point in explaining the concept of "hibernation": "The sleeping hedgehog waits for the spring to burst its metabolism into life" (p. 19).

Thus these concepts can be taught to children and we should not expect children to spontaneously know about them. So as to uproot

existing misconceptions, additional concepts must often be simultaneously introduced. Conceptual clarity obviously depends on the development of a whole framework of concepts. This investigation makes clear the fact that evaluation, even when conducted in the summative phase of a project, can pinpoint content dificiencies which need to be ameliorated. Each and any penetrating program evaluation can provide feedback for future lesson refinement and should therefore be exploited in its formative role. Indeed the most important role of curriculum evaluation should be to provide feed-back on ways to improve the curriculum; and if the evaluation is part of an educational research project, to provide insight into the educative process.

Finally, the conclusions of this paper clearly exemplify the fact that curriculum developers and instructional planners need to take into account the "excess baggage" that their instrumental content may carry. That is, they need to examine which additional concepts are implied in the exemplars used, and cannot take for granted that all that needs to be known, is indeed known by the students.

Summary

In this paper I have provided a general descriptive model of program development, implementation, and evaluation based on an actual case study. The model presented has three phases which can be characterized as the pre-developmental, curriculum development, and research. Throughout the model, two different roles of evaluation were emphasized

during each of the different phases. Data were presented to highlight the need for continuous program evaluation, even after program development has been completed. Thus research can and should provide a basis for program improvement by offering insights into previously unrealized deficiencies. Indeed, all evaluation information, particularly that learned from research and summative evaluation, can provide data pertinent to possible program improvement. Educational evaluation should be continuous and organic.

NOTES

1. Notice that because evaluation is subject to evaluation the concept of "evaluation" has infinite regress possibilities. This is a problem which we do not intend to discuss in this paper. Nevertheless, one should recognize that this very exposition, in a sense, an evaluation of the processes of evaluation (a metaevaluation) which have occurred during the development and implementation of one program.
2. Scriven's paper, along with a number of other classics in educational evaluation, can be found in Worthen and Sanders (1973). That text should provide the primary foundation for educational evaluation which is lacking in this paper.
3. Scriven's paper covers the following concepts: "Goals of Evaluation Versus Roles of Evaluation; Formative and Summative Roles"; "Professional Versus Amateur Evaluation"; "Evaluation Studies Versus Process Studies"; "Evaluation Versus Estimation of Goal Achievement"; "Intrinsic Evaluation Versus Payoff Evaluation"; "Practical Procedures for Hybrid Evaluation"; "The Possibility of Pure Payoff Evaluation"; "Comparative Versus Noncomparative Evaluation"; "Practical Procedures for Central Group Evaluation"; "Criteria of Educational Achievement for Evaluation Studies"; "Values and Costs"; "A Marginal Kind of Evaluation - Explanatory Evaluation".
4. See Worthen and Sanders 1973, pp. 62-63.

5. The A-T adit to instruction has been described by Postlethwait et al. (1972) and Triezenberg (1972). In both of these collections, Novak has written a chapter relevant to the A-TESP. These have and will henceforth be referred to as Novak 1972a and Novak 1972b, respectively.

6. A summary can also be found in Novak (1977).

7. Op. cit., p. 110. Novak refers here to Novak (1966) where he reported on early lessons developed to teach plant growth; and to Bridgeham (1969) who developed the A-T lessons on electrostatics.

8. The A-TESP is conceptually-oriented; thus the curricular emphasis has focused on concept acquisition. The A-TESP concepts were selected from NSTA guidelines (1964). Essentially, there are only a handful of fundamental scientific concepts and ideas which are the underpinnings and cornerstones of the entire scientific enterprise (Novak et al. 1966).

9. Examples from this developmental stage can be found in Hibbard (1971), McClelland (1970), and Nussbaum (1972).

10. The concepts of "curricular content" and "instrumental content" have been delineated by Johnson (1967, 1977) and used by Posner and Rudnitsky (1978).

11. Indeed, one of the purposes of this particular paper is to show that even when a program is considered complete, deficiencies may still exist.

12. This study is reported in Pines (1977, 1978) and in Pines and Novak (1980).

13. Discussions of concept maps in general and of this concept map in particular are beyond the scope of this paper. Pines (1977), Stewart, Van Kirk, and Rowell (1979), and Rowell (1978) delve more thoroughly into these issues.

    Pines et al. (1978)refers to a monograph on the MPCI. Posner et al. (1978) is a monograph on the evaluation of cognitive structure. In the latter a chapter by Pines concerns both the MPCI and the CPA. The reader is directed to these reports for a further discussion of these methodologies. Both can be obtained from the Department of Education, Stone Hall, Cornell University, Ithaca, New York 14853, USA.

14. Pines 1977, Op. cit.

15. An analysis of the strengths and weaknesses of this response appears in Pines (1977). Such details are beyond the scope of this paper and are thus reserved for the reader's independent contemplation and completion. The example is included only to provide an "ideal background" against which certain misconceptions can be compared (cf. Tables 2, 3, and 4).

16. After all, the A-TESP developers knew that most seeds are alive but erroneously assumed that most primary-aged children have similar beliefs.

17. The case may be that the population of children who served in lesson construction studies were fundamentally different from the children in this study. But this author finds such radical changes in children's prior knowledge which could have occurred

in less than 10 years difficult to believe. An alternative explanation would be affiliated with the administration and implementation of the lessons. Mormann - Pines (1980, see also Pines & Pines 1978) found that changes in the operational aspects of the A-TESP have occurred. Perhaps when the lessons are integrated with other classroom activities, when the teacher uses the alternative experiences provided with the lessons, then certain content problems concerning misconceptions are mitigated or eradicated. Nevertheless, the findings of this study strongly urge that the lessons receive an updating. Either the exemplars must be changed, or the implications of the exemplars used must be taken into account and integrated into instruction.

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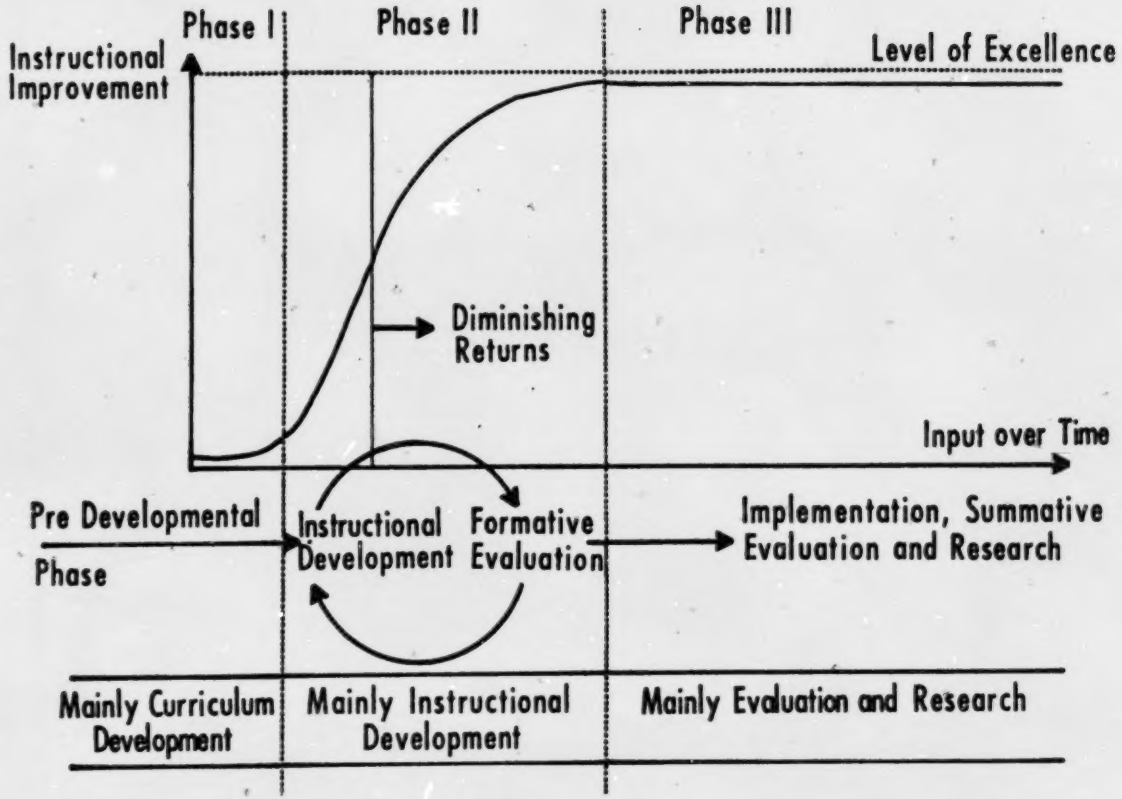

Figure 1: A Model for Program Development and Evaluation

Table 1:

Example #1 from Case Study of Child #27.

Pre II	Post II
3. Real seeds are alive ...	2. If you put water and leave off the top of the thing you put them in so they (seeds) can have air, and you put them in the window, they'll grow into a big plant
10. Like if you plant pea seeds ... you stick them in the ground and cover them up	3. Seeds need water, light, and air
11. In spring they grow up into a plant	4. They (seeds) need light so they can grow; if they don't have light they won't be able to grow.
13. Seeds need water to grow	5. I don't know if these seeds are alive
14. Seeds need soil to grow	7. They (seeds) won't grow alone.
27. The corn needs the sun because it (sun) helps it (corn) to grow	8. There is nothing you can do to make them (seeds) grow because they might be dead and if they're dead they won't grow.
	9. To check if they're (seeds) alive, you have to wait for a few days and if there's water, light, and air they might grow into big plants.
	10. If they (seeds) grow, they're alive
	14. If you put a pea seed in the ground it would probably grow and it would grow vines ...

Table 2:

Example #2 from Case Study of Child #31

Pre II	Post II
4. You can plant seeds	1. These are seeds
5. Some kinds of seeds can make flowers	5. The seeds are like human beings because we (humans) need water and we need air.
7. Seeds ain't alive	7. The seed needs the sun to help it grow
8. When you plant seeds they grow	11. These seeds ain't alive; it doesn't look like they're alive
11. Flowers need water and sun	12. I could tell if they were alive because they'd be growing
14. The same about me and the flowers is that we both need water and we both need sun	15. Plants outside are alive but not them, they're just seeds
	16. If you planted seeds and gave them water and sun and air they would grow
	26. The seeds ain't alive now but they could be (alive) if they had water and sun and air

Table 3:

Example #3 from Case Study of Child #15

Pre II	Post II
1. These are peas	2. Plants will grow if you put the seed in water or sun
3. The peas are dead because they're water	6. The seeds ain't alive yet
4. If you put them (peas) in the ground, they would turn into a pea plant	7. The seeds could be alive if the sun and water helped them
5. The pea plant would be alive	

Table 4:

Example #4 from Case Study of Child #43

Pre II	Post II
1. They're seeds	1. These are seeds
3. The seeds are not alive	2. They're all dried up
5. You can plant the seeds	3. You can plant the seeds
9. The seeds grow into a plant	14. The seeds are not alive because they don't have water.
13. The plant is alive.	15. If they get water they'll grow
	16. When they grow they're alive
	17. When seeds get water, they will be alive

Table 5:

Example #5 from Case Study of Child #67

Pre II	Post II
Control - no Pre II Administered	1. Those are beans; they grow
	2. They (beans) need light and water and soil
	6. The beans are not alive because you can't see any roots or anything
	8. If they have roots and a stem then they're alive and if not then they're not alive
	9. If you took this one bean and gave it water and sun and light it would grow and it would then be alive
	10. The bean is not alive now but it can be alive